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The Cryogenic Dark Matter Search (CDMS) : Present Status and Future

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Abstract. The CDMS collaboration utilizes Ge detectors for their Weakly Interacting Massive Particle (WIMP) search at the Soudan mine, Minnesota. The final data run of CDMS II is complete and a detector upgrade for SuperCDMS has commenced. A SuperTower of five 1-inch thick Ge crystals has been installed and undergoing commissioning. Its surface-event rejection capability should allow SuperCDMS to continue to run background free for the next proposed phases: 15 kg Ge deployment at Soudan, and up to 150 kg Ge deployment at SNOLAB. Recent detector advances to allow a 1 tonne Ge experiment are also discussed.

Keywords: Dark Matter. Cryogenic detectors.
PACS: 14.80 Ly 95.35 +

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INTRODUCTION

The concordance model of Cosmology [1] suggests that 23% of the mass-energy of the Universe is in the form of cold (non-relativistic) dark matter particles that only interact with ordinary matter via the nuclear-weak interaction. The relic density of these particles in our galactic neighborhood is estimated to be 0.3 GeV/cm^3 from the spiral arms' velocity rotation curve [2]. Recent surveys [3] confirm that these particles are in an approximate Maxwellian velocity distribution, with a circular velocity of 210 km/s and a velocity cut-off of ~ 550 km/s.

In these proceedings Cushman reviews the particle physics candidates for cold dark matter and the options for their detection [4]. Here we will focus on direct detection of Weakly Interacting Massive Particles (WIMPs) in the Ge crystals of the Cryogenic Dark Matter Search (CDMS) collaboration [5]. The interaction rate of these WIMPs with nucleons is expected to be less than 1 event per kg of target, per year [2]. Presently CDMS II sets the most stringent exclusion limit for the spin-independent (scalar) WIMP-nucleon cross-section for WIMPs above a mass of 42 GeV/c^2 [5].

COMPLETION OF CDMS II

The Cryogenic Dark Matter Search II (CDMS II) experiment is an array of Ge and Si detectors operated at a temperature of 50 mK in the Soudan Mine, Minnesota, at a depth of 710 m. First results from operating the full five towers of CDMS II were published in January 2009 [5] using data taken from October 2006 to June 2007. Data taking for these 5 towers continued until March 2009. The data from July 2007 to November 2008 has undergone data processing, and analysis for this data set is nearing completion. Announcement of a new result from CDMS II is expected during the summer of 2009.

START OF SUPERCDMS SOUDAN

With the completion of detector fabrication for CDMS II, a 2-year detector R&D program was initiated to scale up the thickness of the Ge detectors and further improve the detector surface-event rejection capability for SuperCDMS [6,7]. During April 2009 the first SuperTower (3 kg of Ge) was installed in the CDMS II Soudan icebox along with the latter 3 towers of CDMS II (also 3 kg of Ge). A comparison of this new SuperTower and a CDMS-II style Tower is shown in Fig. 1. In order to allow equivalent analysis of the stack of five 1-inch thick detectors the SuperTower includes two end-cap detectors, 1 cm thick Ge, at the top and bottom of the stack to veto multiple scattering events and aid in leakage event estimates.

The commissioning phase of this data run is in progress with the 1-inch thick Ge detectors' charge collection at 3 Volt bias performing well. The detectors for the second SuperTower are already fabricated and are half-way through their surface-facility testing program.

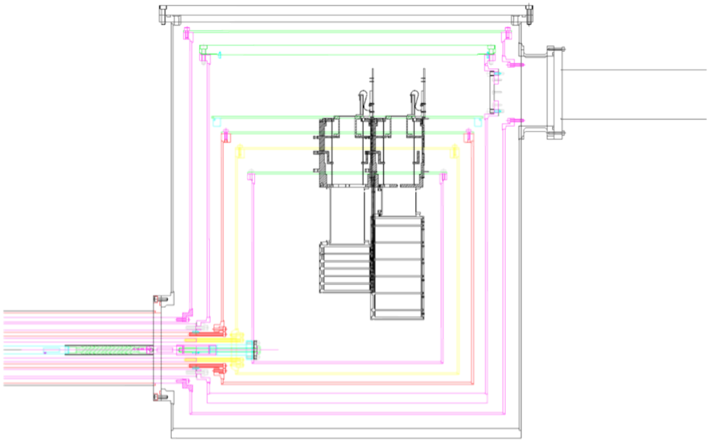

FIGURE 1. Cross-section of the CDMS-II Soudan ice-box showing a SuperTower (black, right) containing five 1-inch thick Ge detectors, next to a CDMS II tower (black, left). The attachment of the icebox to the dilution refrigerator is to the left and the detector electronics read-out stem is to the right.

FUTURE PROSPECTS

During the summer of 2009 we anticipate approval to complete the SuperCDMS Soudan project with a planned additional 3 SuperTowers to be fabricated and run at the Soudan site. The expected WIMP-search sensitivity is shown in Fig. 2 for a nominal WIMP mass of 60 GeV/c^2. If no background (or WIMP signal) events are encountered then the 90% CL exclusion limit would correspond to a WIMP-nucleon cross-section of 5 x 10^{-45} cm^2, a region of interest in a number of Supersymmetric extensions [8,9] to the Standard Model. For the case of an understood background, with low systematic uncertainty and statistically subtracted off, the expected progress is degraded to a square-root of time (indicated by the thick dashed curves in Fig. 2). Dodelson considers these cases further in Ref. [10] for SuperCDMS and other direct-detection approaches. He provides a framework that allows inclusion of estimated systematic error on expected background event rate, and reinforces the desirability of remaining in the zero-background regime.

For SuperCDMS, a study of background sources and detector event-rejection capability [11] suggests that the Soudan site is not deep enough to prevent muon-induced neutrons becoming an irreducible background for SuperCDMS. Thus beyond Soudan we are in discussions to go to a deeper site, for example SNOLAB, around 2012. Although the present SuperCDMS detector surface-event rejection capabilities are adequate for a 100 kg scale experiment [7], approaching a 1-tonne Ge experiment probably requires a change in approach in order to maintain the zero-background regime. We have investigated a reconfiguration of the ionization electrode configuration where inter-leaved electrodes on both surfaces allow an ionization-signal based discrimination technique [12]. Events in the bulk of the crystal generate signals in two charge-readout channels, whereas events near the surface only generate a signal in one charge-readout channel due to the tangential electric fields present.

Recently the Edelweiss Collaboration has demonstrated that such an approach is probably adequate for a tonne-scale Ge experiment [13].

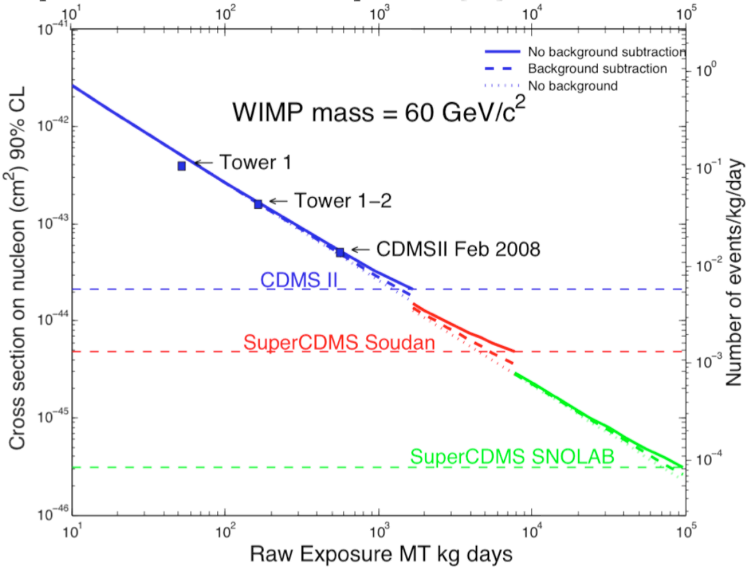

FIGURE 2. Obtained (and projected) WIMP-search sensitivity for CDMS (and SuperCDMS) assuming a WIMP mass of 60 GeV/c^2. The deployed mass for SuperCDMS Soudan (red) is assumed to be 15 kg and for SuperCDMS SNOLAB (green) 150 kg. For the case of zero-background events the sensitivity improves linearly with time (dotted line). After one or two observed background events the advance is slowed, especially if this background cannot be statistically subtracted (solid line). See also Ref. [10].

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